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IMAGE RESTORATION PARAMETER CHOICE - A QUANTITATIVE GUIDE

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ABSTRACT

Quantitative results are presented which should be useful in choosing parameters required for image restoration by Wiener filtering. These results are obtained using a single point spread function and two blurred image lines. Various measures of restored image quality are examined.

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1. Introduction

In this paper quantitative results are presented which should be useful in choosing parameters required for image restoration by Wiener filtering. Discussion is in the context of the package of restoration programs included as part of [8]. The particular techniques used are discussed, and illustrated with examples, in [1-7].

Consider the case of a one-dimensional point spread function (psf) h of extent L pixels which has contributed to a given blurred image b of extent J pixels. b is viewed as resulting from the truncation of a circular blurred image $\hat{b}$ of extent $M = J+L-1$ pixels which is given by $\hat{b} = p \circledast h + n$, where $\circledast$ denotes circular convolution, p is the original image and n is the noise. The problem that the restoration technique solves is: given b and h, find p. Any errors in the estimate of h are considered to be part of n. $\hat{b}$ is deduced from b, by circularly extrapolating it over extent L-1 pixels using linear extrapolation or cubic polynomials. Errors in estimating $\hat{b}$ are also assumed to be part of n. Letting capital letters denote Fourier transformation P, and hence p, is obtained from

$$P = \frac{\hat{B}H^*}{HH^*+\Phi^2} .$$

Here, Φ is the ratio of $|N|$ to $|P|$, which is a function of spatial frequency. In general, the form of Φ is not well known so that it makes sense to assume that Φ is a constant equal to

the ratio of the standard deviations of n and p. This constant must usually be estimated using b, available knowledge of n, experience, and trial and error.

Another practical consideration is the following. Fourier transformation is implemented using the fast Fourier transformation algorithm (FFT). This usually requires that M be a power of 2, which it need not be. To overcome this, $\hat{b}$ and h (in a frame of length M) are linearly interpolated to give $\hat{b}'$ and h' which are both of length K which is a power of 2. The restoration is then carried out to give p', which is then resampled by linear interpolation to give p. A choice must be made for K such that the interpolation will not unduly degrade p.

In Section 2, the effect of restoring the psf itself is considered in relation to the choice of Φ and K. In Section 3, the effect of restoring two image lines is considered in relation to the choice of Φ and the extrapolation technique for obtaining $\hat{b}$ from b. Sections 2 and 3 also give an indication of the improvement in image quality that can be expected with this image restoration technique.

2. PSF considerations

Let h be as indicated in Figure 1. Here, $L = 13$ and h has been formed by the convolution of a single pixel (of value 255) with three normalized rectangular psfs of length 7, 5 and 3 pixels respectively. Quantization was carried out after each convolution. The actual sampled values h_i of h are

1 3 6 10 14 16 18 16 14 10 6 3 1.

The effect of restoring h by itself is now considered. This indicates the effect of the restoration procedure as a function of K and Φ. Three measures of the quality of the restoration are considered. For each of these quality measures, results are plotted as a function of Φ for four cases. For the first case $J = 244$ and $K = 256$. This involves no interpolation. For the next three cases $J = 256$, 512 and 1024 respectively.

The first quality measure is the half width w in pixels of the resultant psf p. This is defined as the distance from the center of h at which p falls to half its central value. The results are shown in Figure 2. If a Φ of less than .01 is acceptable, w can be reduced from its original value by a factor of about 6 for case 1. The increase of w with Φ for case 1 is not smooth because w is not a good measure of resultant psf quality. It is susceptible to the presence of psf sidelobes. For a given Φ, if interpolation is required K must be chosen high enough so that w is a satisfactory approximation

to that for case 1. For example, if $\Phi = .01$, K could be 512, but if $\Phi = .05$, K could be 256. w is reasonably stable to errors of up to 50% in Φ.

The second quality measure is the value v of p at the center of h when p is normalized so that

$$\sum_{i=1}^{M} p_i = 1.$$

The results for v are shown in Figure 3. v is not a good quality measure for low Φ as it can then vary considerably. Nevertheless, for a given Φ, it does indicate the minimum acceptable K when interpolation is required.

The third and best quality measure (in agreement with [4]) is the value u of p at the center of h when p is normalized so that

$$\sum_{i=1}^{M} {p_i}^2 = 1.$$

The results for u are shown in Figure 4. Note that the improvement in u that the restoration produces is less dramatic than that for v and w. As Φ increases towards 0.05, the effect of interpolation becomes negligible. The results in Figure 4 are typical of what can be expected in one and two-dimensional image restoration problems.

3. Restoration Examples

The distinction is made here, as in [2], between class S and class G blurred images. Class S blurred images are surrounded by a uniform background so that the truncation of the full blurred image by the recording frame causes no loss of information. On the other hand, truncation by the recording frame does cause information loss for class G images. Edge extension by linear extrapolation is exact for class S images.

Figure 5 shows an artificial image line of length 256 pixels. Each pixel value is an integer. This was blurred by a rectangular psf of length 13 pixels, rounded to the nearest integer and truncated by the recording frame to give a class G blurred image of length 244 pixels. This image was then restored using linear edge extension. Figure 8 shows the mean absolute error between the restored image and the original image. The above rounding to the nearest integer adds noise to the given blurred image which is approximately uniformly distributed from -.5 to .5. The standard deviation of the blurred image is 16.3. Thus an estimate for the best value of Φ would be $.5/(16.5 \times \sqrt{3})=.02$. This is in reasonable agreement with Figure 8. Figure 8 also shows that the mean absolute error is stable to fairly large errors in the choice of Φ.

Next the first 200 pixels from the image in Figure 5 were padded out with zeros to give an image of length 256. This

was blurred with the same psf used in Figure 8 to give a class S blurred image. Results obtained restoring this image are shown in Figure 9 for the cases when no noise, and uniformly distributed noise from -1 to 1, and from -3 to 3 were added to the blurred image. The results for no noise are in good agreement with Figure 8. This is because the particular form chosen for Figure 5 causes linear edge extension to be accurate. The improvement in mean absolute error decreases as the best Φ, for a given noise level, increases.

Figure 6 is a 128 pixel image line. Blurring it with a 13 pixel rectangular psf as before gave Figure 7, which was truncated to give a class G blurred image of length 116 pixels. Restoring this using linear and cubic edge extension gave the results in Figure 10. Note that in this more typical example cubic edge extension performs significantly better than linear edge extension. In the cubic case the mean absolute error is reduced by a factor of 3. It is appropriate to point out that when applying these techniques to large blurred images as in [6], a further reduction in mean absolute error can usually be achieved. This is done using a priori knowledge about the smoothness of the given blurred image and the restored image to select filters such as median filters which can be used to reduce the noise level and hence the best Φ.

4. Conclusions

The results presented here show how the parameters selected for use in image restoration of class G images by Wiener filtering interact. This should allow these parameters to be selected with greater confidence.

References

1. M.J. McDonnell, Nonrecursive Digital Image Restoration, Ph.D. dissertation, Dept. of Electrical Engineering, University of Canterbury, Christchurch, New Zealand, December 1975.

2. M.J. McDonnell and R.H.T. Bates, Preprocessing of degraded images to augment existing restoration methods, Computer Graphics and Image Processing 4, 1975, 25-39.

3. M.J. McDonnell and R.H.T. Bates, Restoring parts of scenes from blurred photographs, Optics Communications 13, 1975, 347-349.

4. M.J. McDonnell, Nonrecursive image restoration using a finite filter array, Optik 43, 1975, 159-174.

5. M.J. McDonnell, W.K. Kennedy and R.H.T. Bates, Identifying and overcoming practical problems of digital image restoration, New Zealand Journal of Science 19, 1976, 127-133.

6. M.J. McDonnell, Restoration of VOYAGER 1 images of Io, to be published in Computer Graphics and Image Processing, 1980.

7. M.J. McDonnell and A.D.W. Fowler, Computer analysis of suspected Clarence River "UFO images" filmed by TV1, PEL DSIR Report No. 632, February 1979.

8. M.J. McDonnell, Physics and Engineering Laboratory Fortran image processing system, University of Maryland, Computer Science TR-941, September 1980.

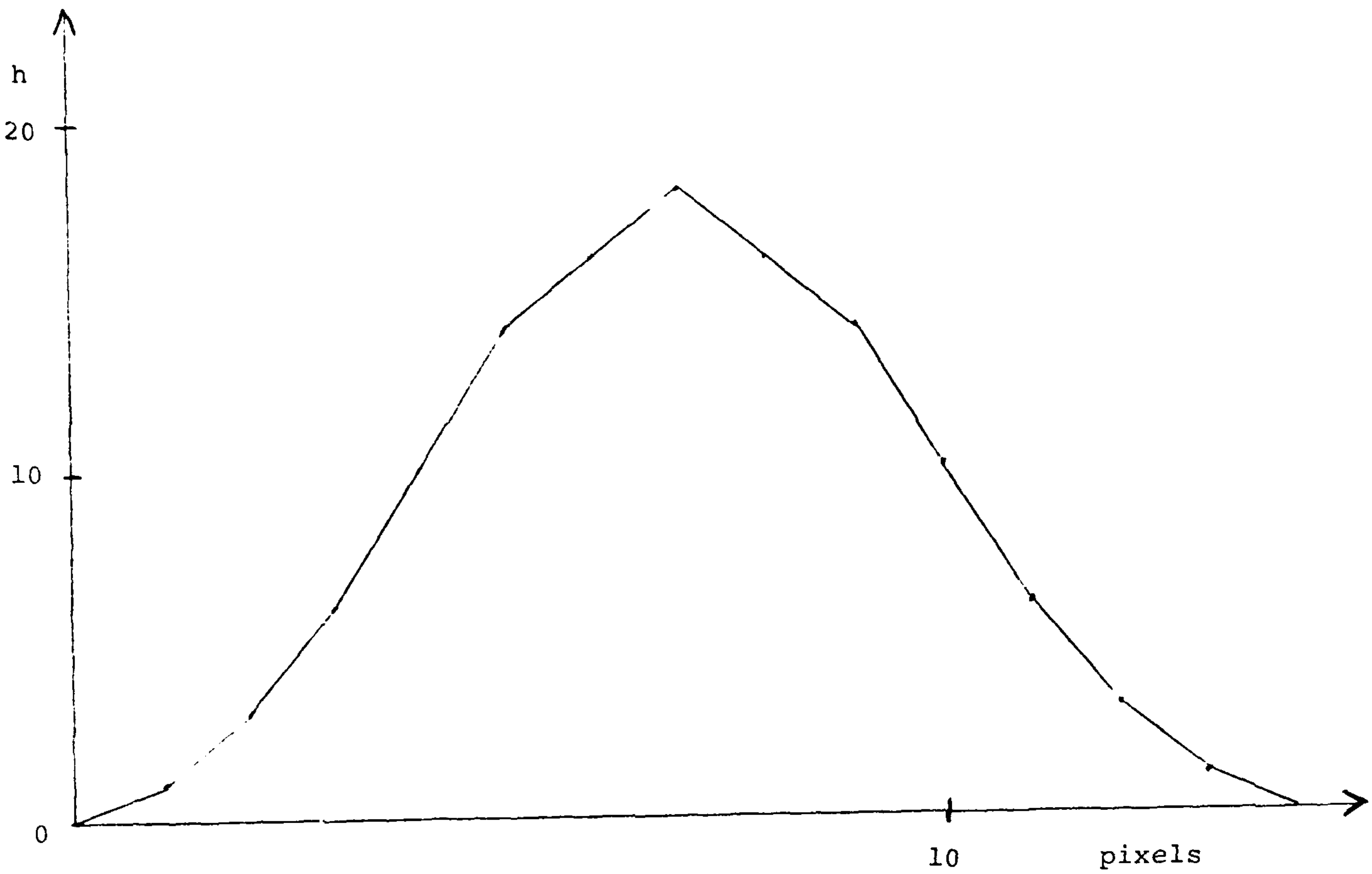

Figure 1. Psf h.

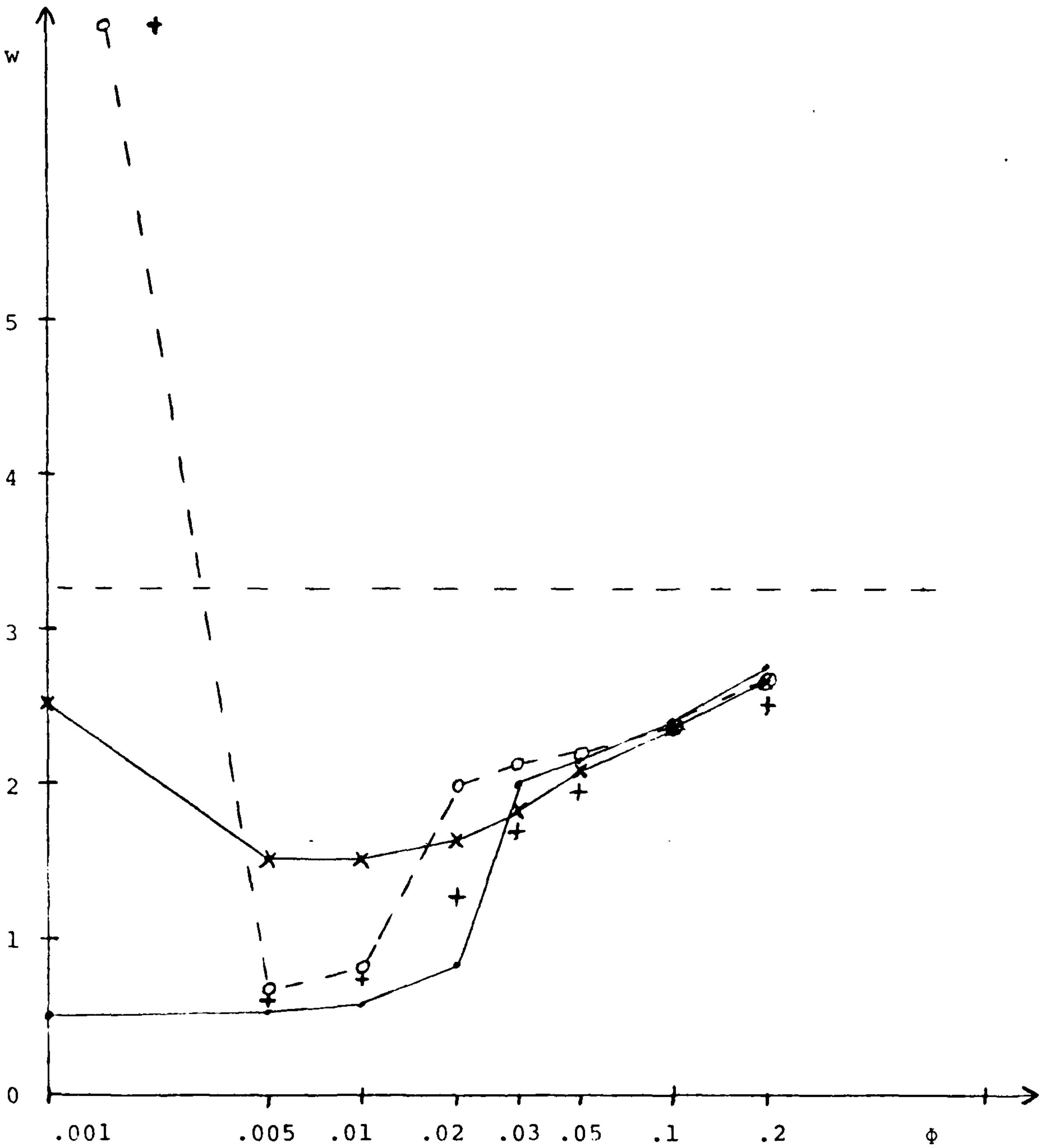

Figure 2. Half width w as a function of Φ for four cases.

Case 1(·), J=244, K=256,

Case 2(x), J=256, K=256,

Case 3(0), J=256, K=512,

Case 4(+), J=256, K=1024.

The dashed horizontal line shows w for the original psf h.

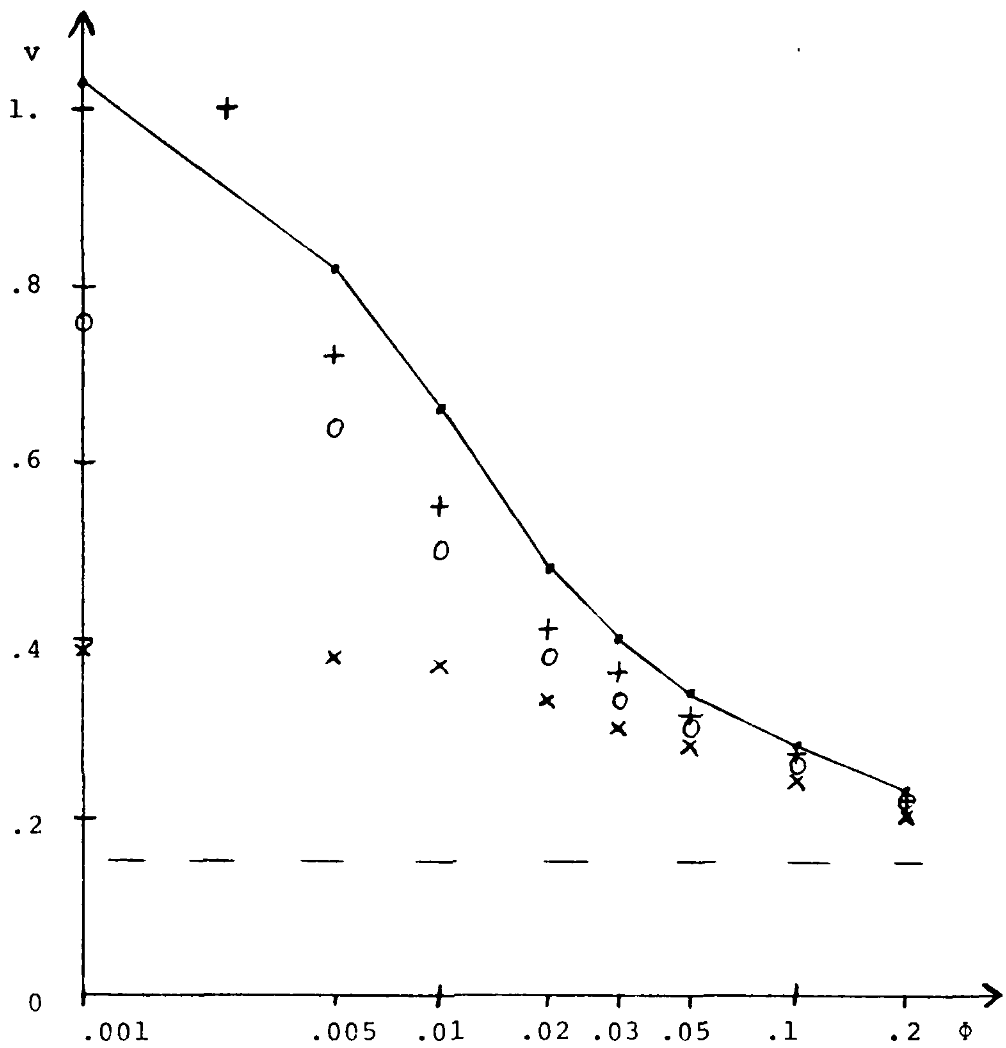

Figure 3. Half width v as a function of Φ for four cases.

Case 1(·), J=244, K=256,

Case 2(x), J=256, K=256,

Case 3(0), J=256, K=512,

Case 4(+), J=256, K=1024.

The dashed horizontal line shows v for the original psf h.

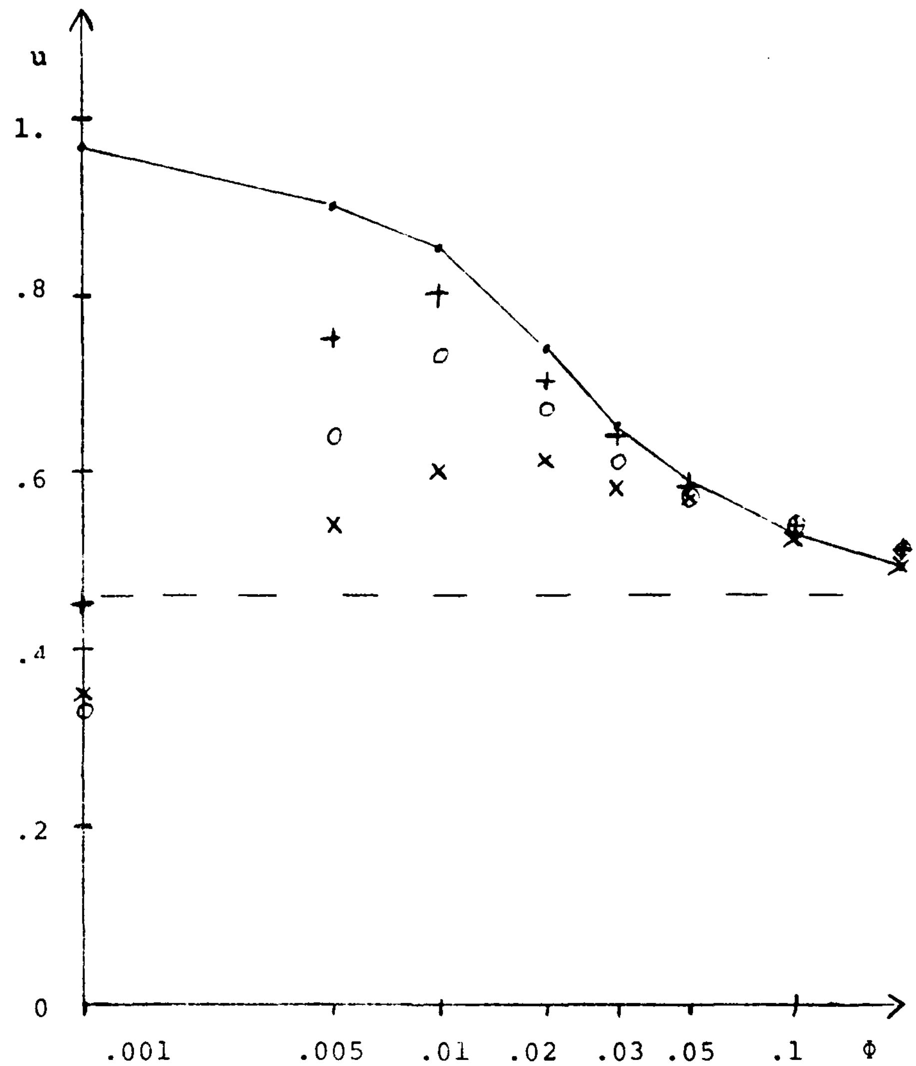

Figure 4. Half width u as a function of Φ for four cases.

Case 1(·), J=244, K=256,

Case 2(x), J=256, K=256,

Case 3(0), J=256, K=512,

Case 4(+), J=256, K=1024.

The dashed horizontal line shows u for the original psf h.

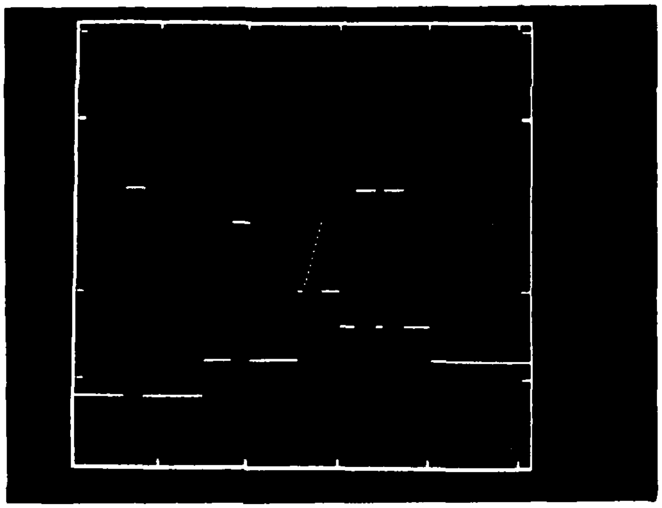

Figure 5. Original artificial image line p, length 256 pixels.

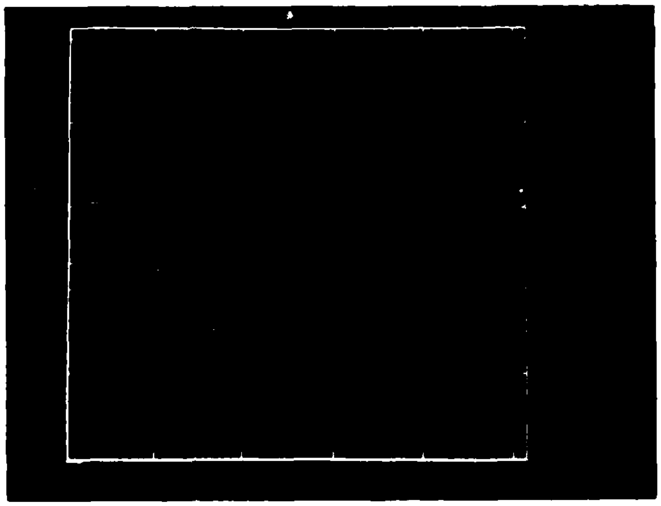

Figure 6. Original image line p, length 128 pixels.

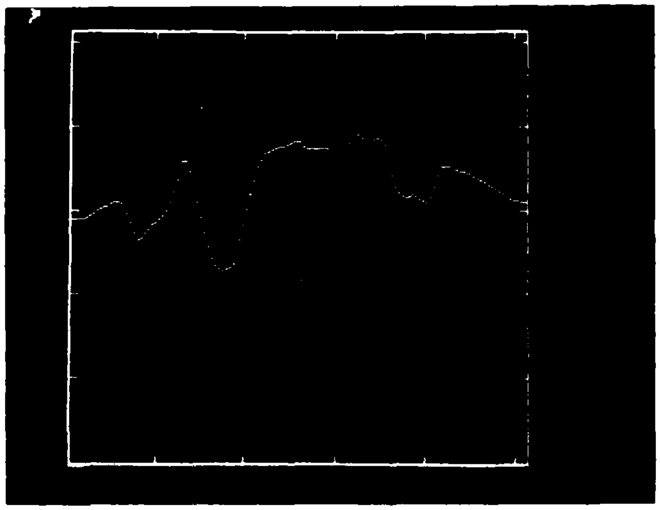

Figure 7. Result of convolving the line in Figure 6 with a rectangular psf of length 13 pixels. b of length 116 pixels was obtained by truncating this image line which is of length 128 pixels.

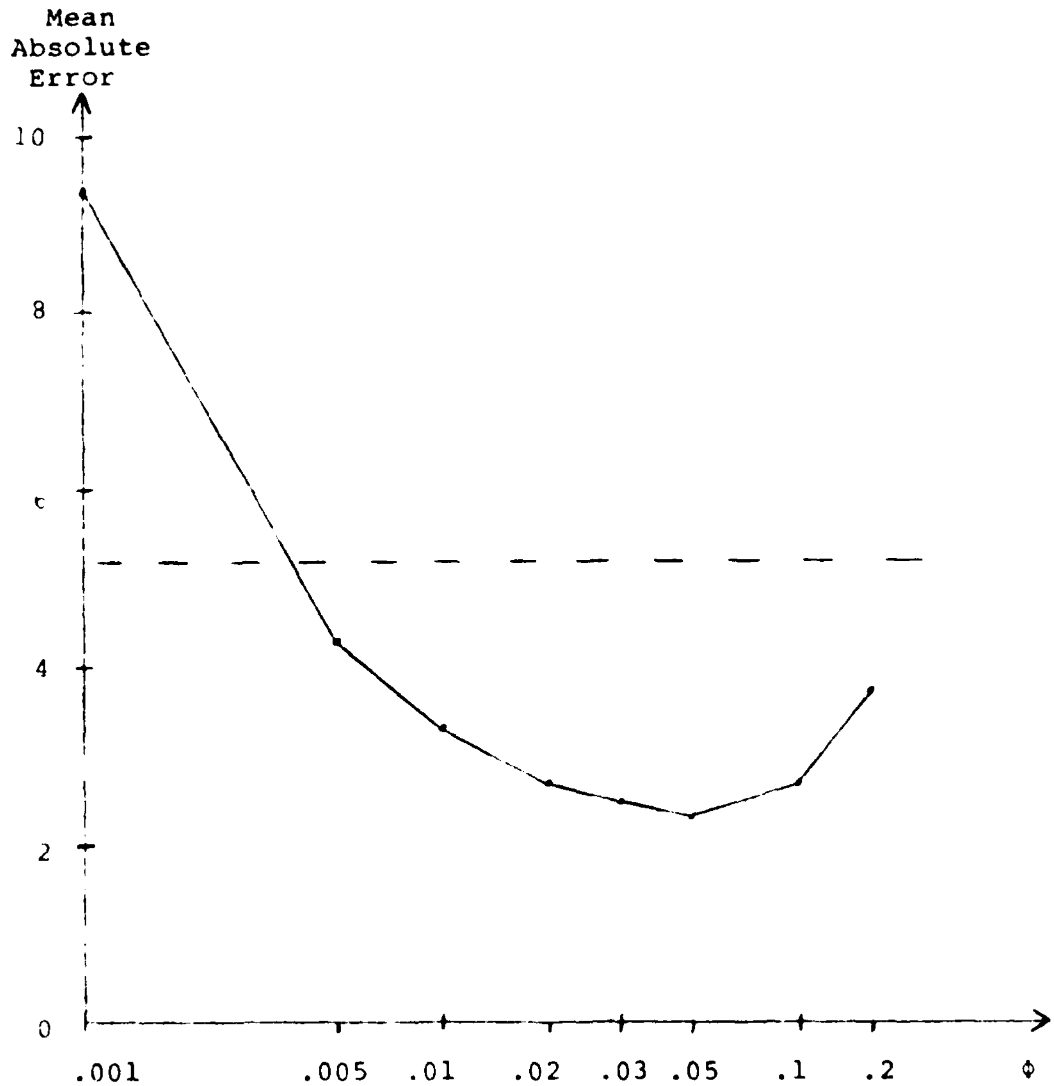

Figure 8. Restored image mean absolute error as a function of Φ. The class G 244 pixel blurred image was produced from Figure 5 by blurring with a rectangular psf of length 13 pixels. The dashed line shows the mean absolute difference between the original and blurred images.

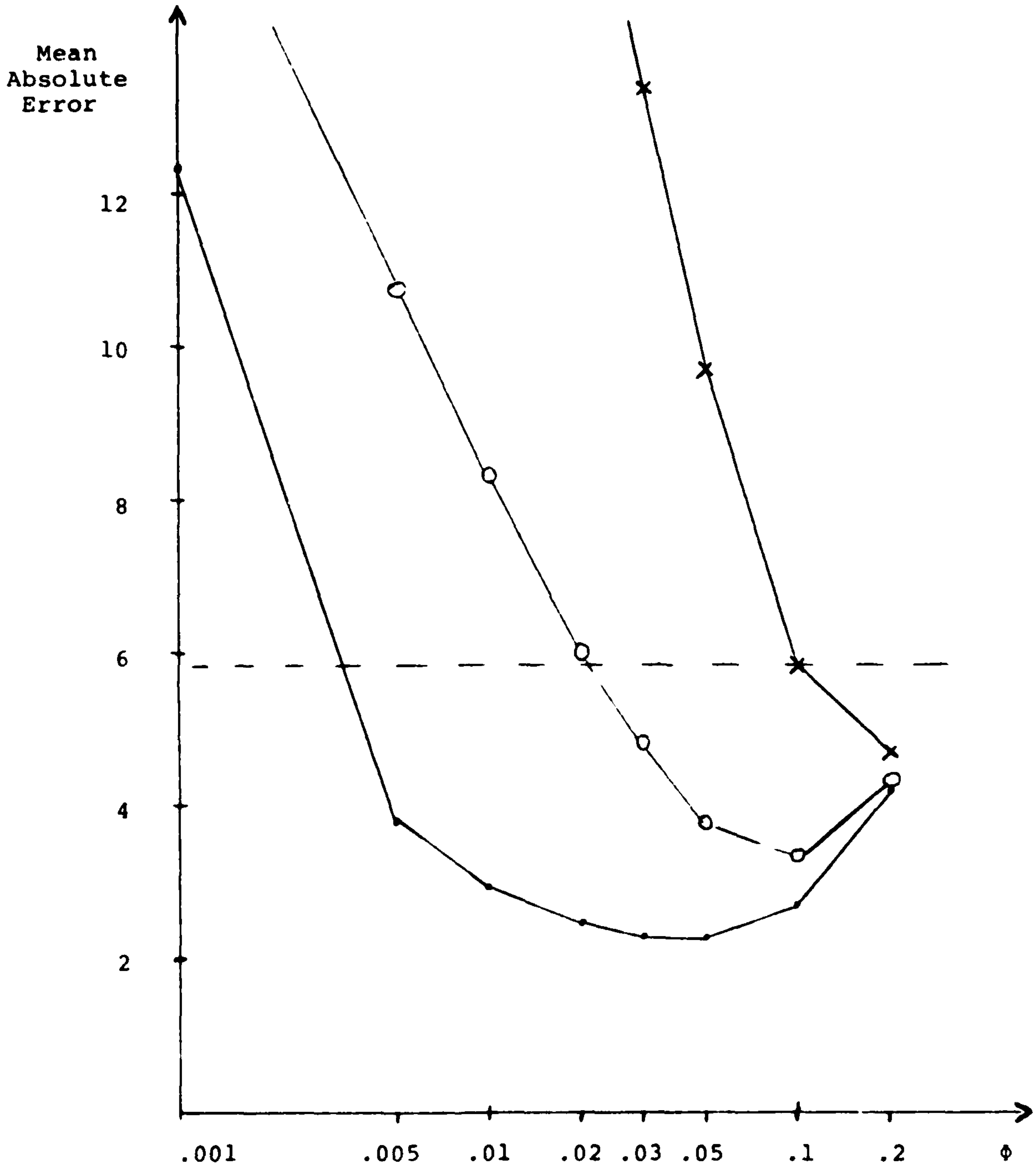

Figure 9. Restored image mean absolute error as a function of Φ for the class S blurred image produced from Figure 5. The dashed line shows the mean absolute difference between the original and blurred images in the absence of additional noise.

· - no additional noise added

o - additional uniform noise ranges from -1 to +1.

x - additional uniform noise ranges from -3 to +3.

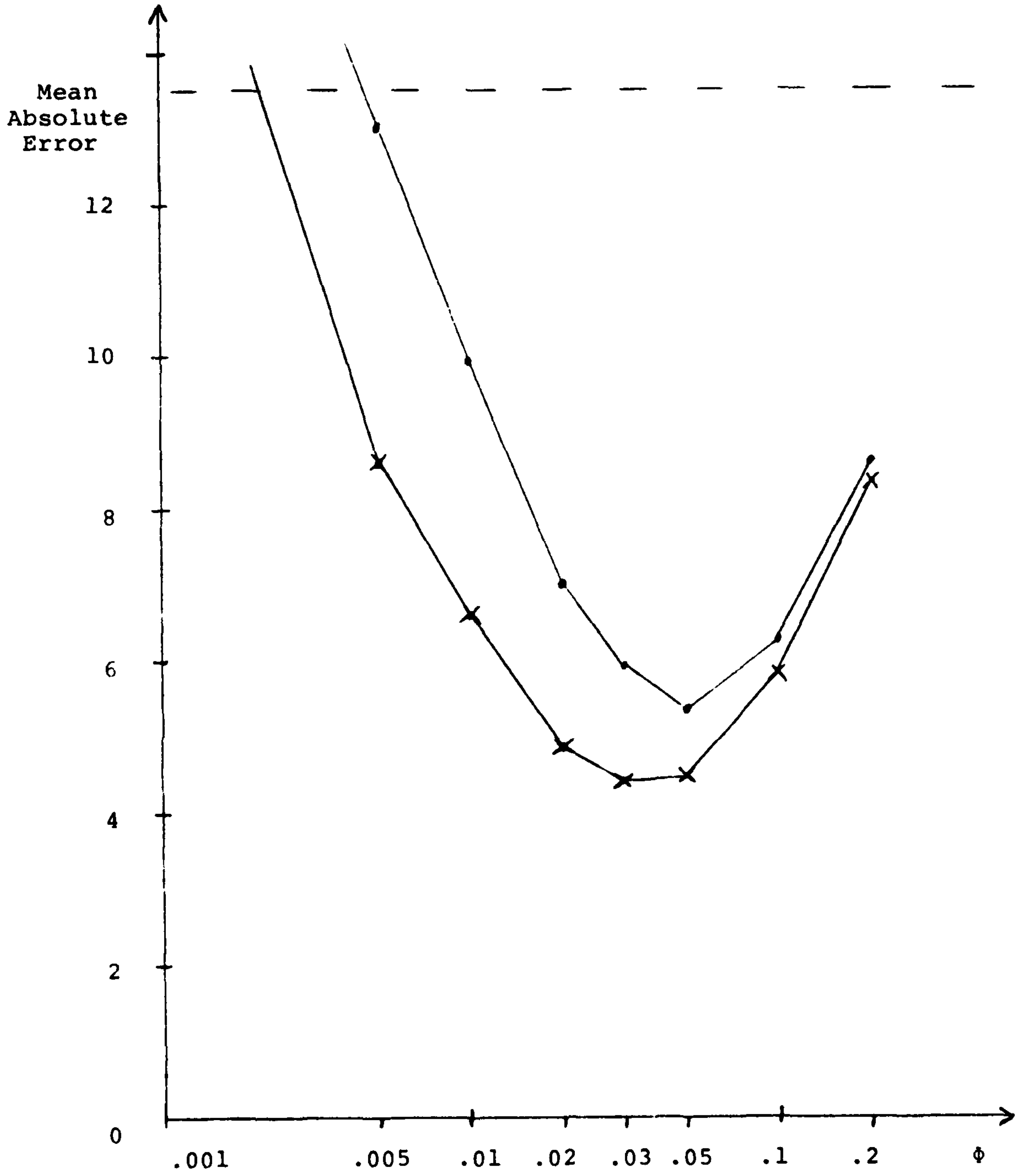

Figure 10. Restored image mean absolute error as a function of Φ for the class G blurred image obtained from Figure 7. The dashed line shows the mean absolute error between the original and blurred images.

· - edge extension by linear extrapolation.

x - edge extension using cubic polynomials.

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